LIGHTWEIGHT CONCRETE PRODUCTION BASED ON INDUSTRIAL WASTE

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Abstract: The increasing demand for sustainable and cost-effective construction materials has prompted the exploration of innovative alternatives to conventional concrete. This study investigates the production of high-performance lightweight concrete utilizing industrial waste such as crushed plastic, glass, and demolition debris. The research highlights the selection of materials, mix design, experimental procedures, and evaluates the mechanical, thermal, and environmental performance of the resulting concrete. Results indicate that incorporating industrial waste materials significantly reduces density and enhances thermal insulation while maintaining adequate compressive strength. The findings support the environmental and economic feasibility of waste-based lightweight concrete for modern construction applications.

Keywords: Lightweight concrete, Industrial waste, Crushed plastic, Crushed glass, Demolition debris, Sustainable construction, Thermal insulation, Circular economy

1.Introduction

The construction sector is one of the leading contributors to environmental degradation due to the extensive consumption of raw materials, energy, and the generation of construction and demolition waste. According to the International Energy Agency (IEA), the global building and construction industry accounts for approximately 39% of global carbon dioxide (CO_2) emissions, a significant portion of which stems from the production and use of traditional concrete. The extraction of natural aggregates such as gravel and sand, and the manufacture of Portland cement, further contribute to land degradation, resource depletion, and greenhouse gas emissions. In parallel with rapid urban expansion and infrastructure development, especially in developing countries, the demand for sustainable and environmentally responsible construction materials has become critical. The adoption of eco-efficient materials that not only reduce environmental burdens but also offer cost advantages is gaining momentum globally. One promising solution is the development of lightweight concrete incorporating industrial waste, which addresses multiple sustainability challenges simultaneously: waste management, resource conservation, and climate change mitigation.

Lightweight concrete, characterized by lower density compared to traditional concrete, provides advantages such as reduced structural loads, easier handling and transportation, and improved thermal insulation. These benefits make it especially suitable for high-rise buildings, partition walls, prefabricated elements, and renovation projects. When produced using recycled materials, lightweight concrete also serves as a platform for implementing circular economy strategies in construction, wherein waste products are reused and reintegrated into the value chain. This study focuses on producing lightweight concrete using readily available industrial waste materials such as crushed plastic from post-consumer PET bottles, crushed glass from bottle and industrial scraps, and demolition debris consisting of concrete and masonry fragments. These materials are abundant, non-biodegradable, and often disposed of in landfills, contributing to long-term environmental issues. By redirecting such waste streams into construction applications, it is possible to not only reduce the ecological footprint of building materials but also mitigate the solid waste crisis faced by many urban areas.

The objective of this study is to evaluate the technical, environmental, and economic feasibility of integrating these industrial wastes into lightweight concrete blocks for both structural and non-structural applications. The research explores material selection, mix design, production methodology, and performance analysis through laboratory testing. Key parameters such as compressive strength, density, thermal conductivity, water absorption, and fire resistance are examined. Additionally, the broader environmental and economic implications are assessed, contributing to the advancement of sustainable construction practices in line with global climate and development goals.

2. Materials and Methods

Materials: This study used a combination of conventional and recycled materials to produce lightweight concrete. The primary binder was Ordinary Portland Cement (OPC), while clean river sand served as the fine aggregate.

The industrial waste materials included:

- Crushed plastic: Post-consumer PET bottles and containers.
- Crushed glass: Discarded glass bottles and industrial glass waste.
- Demolition debris: Recycled concrete and brick fragments from demolished buildings.

The mix design was proportioned by weight as follows:

- Cement – 40%
- Industrial waste – 30%
- Sand – 20%
- Water and plasticizer – 10%

This ratio was selected to achieve a balance between strength, weight reduction, and environmental benefit.

Preparation Process: Waste Processing: The raw waste materials were first processed using specialized equipment:

- Plastic shredder: A 7.5 kW industrial-grade unit was used to shred PET plastics. Equipment cost ranges from $3,500 to $5,000.
- Glass crusher: A machine with a processing capacity of 500 kg/hour was used to crush glass waste. Price range: $4,500–$7,000.
- Concrete crusher: A heavy-duty crusher capable of processing demolition debris. Estimated cost: $10,000–$20,000.

Mixing: The dry materials — cement, sand, and processed waste — were mixed thoroughly in a concrete mixer until a uniform blend was achieved. Water and a plasticizer were then added to ensure proper workability.

Molding and Curing: The specimens were cured in water for 28 days under controlled conditions (temperature 20–25°C, relative humidity >90%). This ensured proper hydration and strength development.

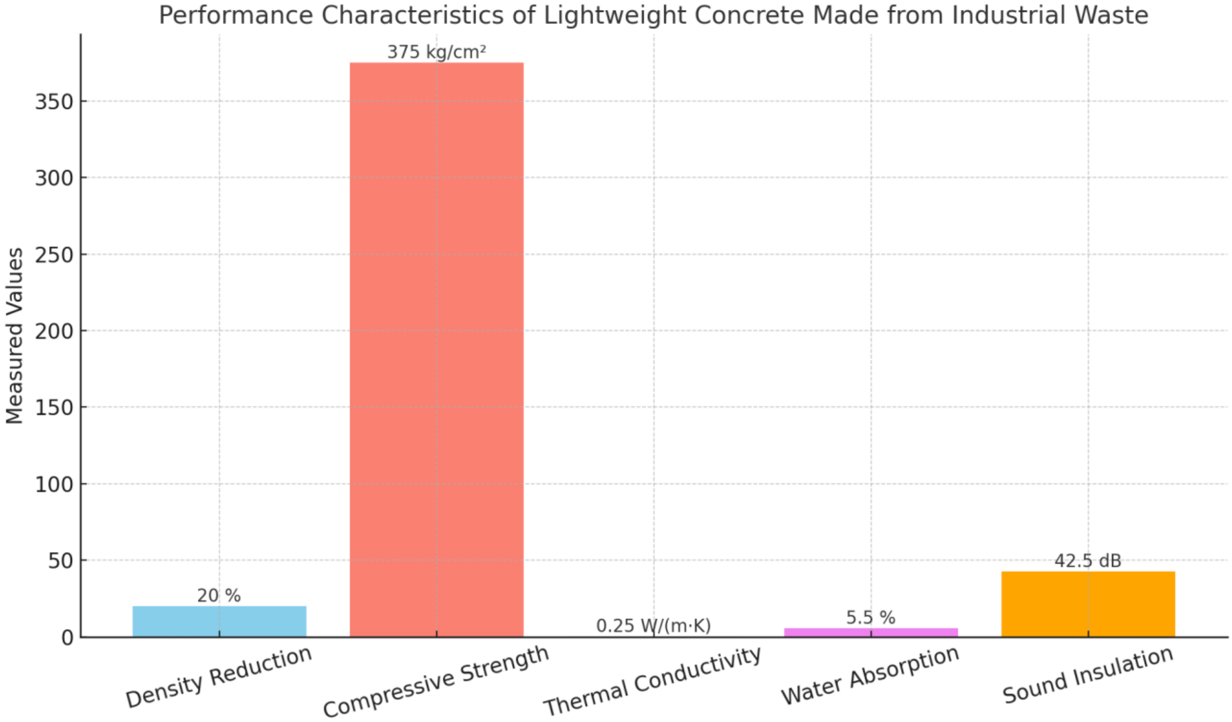
Testing Parameters: After curing, the concrete specimens were tested in the laboratory for the following key performance indicators:

- Compressive Strength: To assess load-bearing capacity.
- Density: To determine material weight and porosity.
- Thermal Conductivity: To evaluate insulation properties.
- Water Absorption: To measure moisture uptake.
- Fire Resistance: To assess behavior under high temperatures.
- Acoustic Insulation: To test sound-absorbing capabilities.

These tests provided a comprehensive understanding of how industrial waste materials affect the mechanical and thermal performance of lightweight concrete. The results are presented and analyzed in the next section.

3. Results

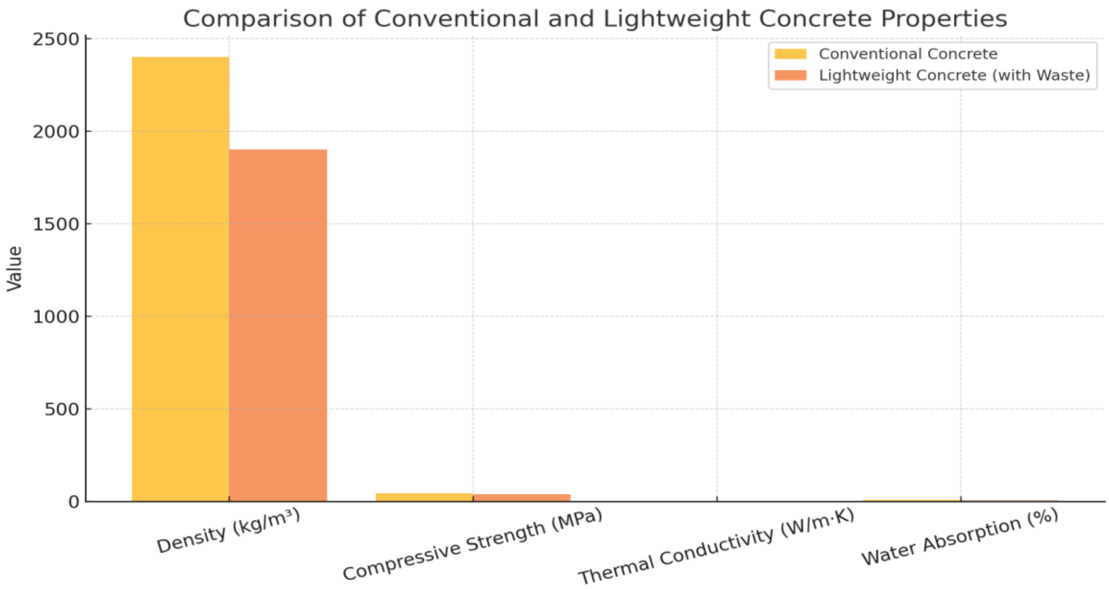
Property	Result	Remark
Density	20% lighter than M400 concrete	Enhances handling and reduces load
Compressive Strength	M350–M400	Suitable for load-bearing applications
Thermal Conductivity	0.25 W/(m·K)	Good insulation performance
Water Absorption	5–6%	Requires protective coating for exterior use
Surface Finish	Smooth, uniform	Suitable for direct painting or plastering
Fire Resistance	Passed standard tests	Meets construction safety requirements
Sound Insulation	40–45 dB	Effective for urban environments



4.Discussion

The findings demonstrate that the integration of crushed industrial waste into concrete not only reduces weight and improves insulation but also supports sustainability goals. The lighter density facilitates easier transportation and construction, while the thermal performance can lead to energy savings in buildings. Crushed plastic and glass contribute to improved insulation, while demolition waste ensures resource recovery.

Economically, the use of waste materials results in a 15–25% reduction in production costs due to decreased reliance on virgin raw materials.



These savings, coupled with environmental advantages such as reduced landfill use and emissions, highlight the feasibility of this approach for large-scale adoption.

However, water absorption remains a concern, necessitating surface treatments. Also, variability in waste properties requires consistent processing and quality control. Future research should address particle grading, advanced admixtures, and long-term durability.

5.Conclusion

This study demonstrates the technical and environmental feasibility of using industrial waste materials — including crushed plastic, glass, and demolition debris — in the production of lightweight concrete. The results indicate that such concrete can achieve adequate compressive strength for both structural and non-structural applications while offering enhanced thermal insulation, reduced density, and moderate water absorption.

Incorporating waste materials in concrete production not only helps reduce dependency on natural resources but also diverts significant volumes of waste from landfills. This contributes to cleaner urban environments and supports global efforts to reduce construction-related carbon emissions. Moreover, the use of recycled materials was shown to reduce production costs by up to 25%, making the solution economically attractive for large-scale applications. From a sustainability perspective, this approach aligns closely with the principles of the circular economy by closing material loops and promoting resource efficiency. The improved thermal properties of the concrete can also contribute to energy savings in buildings, reducing operational emissions over the structure’s lifetime.

While some challenges remain — such as maintaining quality with variable waste inputs and ensuring long-term durability — the findings provide a strong foundation for further research. Future studies may explore optimized mix designs, additive technologies, and field-scale implementations to enhance performance and scalability.

In conclusion, the use of industrial waste in lightweight concrete production presents a practical, cost-effective, and eco-friendly alternative to conventional materials. Its widespread adoption can play a critical role in transitioning the construction industry toward more resilient, sustainable, and low-carbon building practices.

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